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Reference: EPA Contract No. 68-W-02-019; EPA Work Assignment No. R05902; Corrective Action Support; USS Lead Refinery, Inc., East Chicago, IN; EPA ID No. IND047030226; Characterization of Metals in Soil in the Vicinity of the USS Lead Site, East Chicago, Indiana; Task 02 Deliverable

Dear Mr. Wojtas:

Enclosed please find TechLaw's report on the Characterization of Metals in Soil in the Vicinity of the USS Lead Site, East Chicago, Indiana. For your convenience, this report has been provided in WordPerfect format and provided directly to Ms. Mirtha Capiro, the EPA Technical Lead for this project.

TechLaw was tasked, through the Technical Direction Memorandum dated April 25, 2003, and subsequent correspondence with Ms. Mirtha Capiro, to draft this report. TechLaw has prepared this report to present data on the nature of metals in soil in on- and off-site areas.

If you have any questions, or wish to further discuss this report, please feel free to contact either myself, Mr. Todd Quillen at (617)720-0320 x124 or Ms. Kristi Pawski at (312) 345-8963.

Sincerely,

John G. Koehnen  
Regional Project Manager

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**CHARACTERIZATION OF LEAD AND OTHER METALS IN  
SOIL IN THE VICINITY OF THE  
USS LEAD SITE, EAST CHICAGO, INDIANA**

**USS LEAD REFINERY, INC.  
EAST CHICAGO, IN  
EPA ID NO. IND047030226**

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**USS LEAD REFINERY, INC.  
EAST CHICAGO, INDIANA**

**CHARACTERIZATION OF METALS IN SOIL IN THE VICINITY OF THE  
USS LEAD SITE, EAST CHICAGO, INDIANA**

## **1.0 INTRODUCTION**

The purpose of this report is to present analytical results for samples collected on- and off-site of the USS Lead Refinery (USS Lead) Site, a former lead smelting and refining operation, in East Chicago, Indiana. On-site samples were collected from undisturbed areas in an attempt to understand characteristics of contamination associated with the USS Lead site. Off-site samples were collected from areas that were not visibly disturbed in order to understand the concentrations and characteristics of lead and other metals. Although the sample areas were not visibly disturbed, the study area is developed and the sampling locations may have complex histories related to the use of fill, landscaping, chemical application, and other anthropogenic factors that were not characterized in this study. Nevertheless, the representativeness of the sampling locations were visually assessed prior to sampling.

Analytical results from the collected samples were evaluated to ascertain whether airborne contamination related to the USS Lead facility that warrants further investigation is present within the study area. The analytical results from off-site areas was compared to analytical results from the USS Lead site to assist in the determination of whether there is USS Lead contamination in the off-site areas.

TechLaw, Inc. received technical direction from the U.S. EPA Region 5, on May 9, 2002 to conduct split sampling and provide analytical assistance in support of the Modified RCRA Facility Investigation (MRFI) activities at the USS Lead site. Chemical analysis of samples was conducted by a TechLaw Team laboratory, American Analytical Testing Services (AATS) using inductively coupled plasma/mass spectrometry (ICP/MS) methods. Electron microprobe analysis (EMPA) was conducted by the Laboratory for Environmental and Geological Studies (LEGS) at the University of Colorado in Boulder. This report describes the sample collection and preparation, presents the results of the analysis, and provides an evaluation of the results.

## **2.0 SITE DESCRIPTION AND HISTORY**

The USS Lead site is located in East Chicago, Lake County, Indiana (Figure 2-1). The area of the site is approximately 79 acres. A 14 acre Corrective Action Management Unit (CAMU) and other disturbed areas occupy approximately 35 acres of the site. The CAMU is present in the eastern portion of an upland area of the site. The CAMU represents an artificial rise in topography (i.e., a relatively expansive mound with a slope of approximately 10 to 15%) and is currently covered with a 3-foot deep, native sand cover and an engineered cap. The cover has been planted with native vegetation. The CAMU is adjacent to a developed roadway to the east

(Kennedy Avenue), an open water body (created during excavation of the former slag pile) immediately to the south, and low-lying wetland areas to the south and southwest. Upland areas occur to the north, and a relatively undisturbed, combined upland and remnant dune swale habitat occurs immediately to the west and northwest.

The USS Lead site lies in the Calumet Lacustrine Plain. The Calumet Lacustrine Plain is characterized by a flat to gently undulating surface that slopes gently to Lake Michigan (USGS, 2001). The sands that are common in the upper portion of the Calumet Lacustrine Plain are dune, beach, and lacustrine sediments that may contain thin, discontinuous layers of muck, peat, and organic material. Site specific geology has been characterized in the Draft Final MRFI Report (USS Lead, 2004) and other site documents. Borings at the USS Lead site indicate that sand is present from ground surface to a depth of 25 feet. The sands are underlain by a clay-rich unit described as the Wadsworth Till. Generally there are three soil types present in the vicinity of the USS Lead Site: UR (Urban Land), CA (Carlisle Muck [for example, wetland areas in southwest portion of the site]), and OkB (Oakville-Tawas complex [for example, upland areas in western portion of the site]).

USS Lead was a former secondary lead smelter and reprocessor of lead-acid batteries. The facility was a generator and owner/operator of a treatment and storage facility and disposed of hazardous wastes (EPA, 1993). From approximately 1906 to 1920 copper smelting operations took place at the site. From 1920 to approximately 1973 USS Lead conducted primary lead smelting operations including lead refining to produce high quality lead which was free of bismuth. It was noted that the treatment of bismuth dross yielded metals containing gold, silver, and metals of the platinum group. In 1973 USS Lead converted their operations to secondary lead smelting. The secondary refinery operations included: battery breaking with tank treatment of spent battery acid at a rate of 16,000 gallons per day; sulfuric acid treatment with storage of calcium sulfate sludge in a waste pile and generated at 1.5 tons per day; baghouse dust collection with storage in on-site waste piles of up to 8,000 tons of baghouse flue dust; and blast furnace slag disposal, which was deposited in the wetland adjacent to the facility (EPA, 1993). The process area buildings at USS Lead are shown in Figure 2-2. Secondary lead recovery operations ceased in December 1985.

Interim Stabilization Measures have been implemented at the site pursuant to the U.S. EPA Administrative Order on Consent dated November 18, 1993 (EPA, 1993), and the facility has been working to complete IDEM closure requirements as follows: remove lead slag pile; remove battery chips; remove contaminated soils above IDEM human health Industrial lead levels; characterize and remove contaminated sediments within the canal; conduct closure for former hazardous waste management units; and plug sewer and waterlines from the former process area of the facility. Contaminated materials were placed in the on-site CAMU. The CAMU has been covered with an engineered cap and the facility has been pumping groundwater out of the CAMU in attempt to achieve an inward hydraulic gradient.

Environmental remediation at the site has been conducted as a series of soil removals. While removals were conducted in accordance with an approved ISM Work Plan, the removal activities also included many decisions based on field observations and were not necessarily conducted with

EPA or IDEM oversight. The current site conditions are described by the facility in various reports, most recently including the *Draft Final Modified RCRA Facility Investigation (MRFI) Report* (USS Lead, 2004).

The East Chicago area in the vicinity of the USS Lead site has historically supported a variety of industries. In addition to the USS Lead smelting operation, some other industrial operations may have also managed lead and other metals. For example, immediately east of the USS Lead site, across Kennedy Avenue, is a former Dupont site (currently W.R. GRACE & Co., Grace Davison). One of the former processes that historically took place at the Dupont site is the manufacturing of the pesticide lead arsenate. Appendix G of *Grand Calumet River - Indiana Harbor Canal Sediment Cleanup and Restoration Alternatives Project Report* (USACE, 1997) identified U.S. Reduction Co. Aluminum (U.S. Reduction) as one of the industrial sites from Grand Calumet River and Calumet Branch of Indiana Harbor Canal. The U.S. Reduction emissions stack was located north of the Calumet neighborhood north of the USS Lead site. Northwest of the USS Lead site, west of Gladiola Street and north of 151<sup>st</sup> Street, two smelter operations reportedly managed lead and other metals (USS Lead, 2004). A figure from the USS Lead MRFI Report (Figure 23, Examples of Historic Contamination Sources Proximal to USS Lead Refinery, USS Lead, 2004) presents data attributed to a 1930 Sanborn Map and identifies the operations as Anaconda Lead Smelter and International Lead Refining Company. A facility reportedly operated by Eagle-Picher Mining and Smelting, Inc. has also been identified in USS Lead documents as operating in the vicinity of the site (USS Lead, 2004). Figures prepared by USS Lead are included in this report as Figure 2-4 through 2-6, for reference.

A wind rose describing the wind conditions in the vicinity of the USS Lead site is presented as Figure 2-6. The wind rose is based on data from the O'Hare Airport in Chicago, IL. Complete wind data are not available from the Gary Airport, which is geographically closer to the USS Lead site, so data from the O'Hare Airport are considered the best available data. Comparisons of wind data from O'Hare and Gary suggest that the O'Hare data are generally representative of wind conditions in the Gary Airport area (TechLaw, 2002).

TechLaw conducted air dispersion modeling for the USS Lead facility in 2002 (TechLaw, 2002). The deposition pattern generated by the TechLaw air modeling from recognized USS Lead emissions sources shows that USS Lead emissions from secondary smelting operations could have contributed to elevated soil lead concentrations in many areas surrounding the facility. Other sources in the area (e.g., Hammond Lead, Anaconda Lead Smelter, the International Lead Refining Company, the Eagle-Picher Mining and Smelting, Inc.) were not considered in the air modeling that was conducted yet the modeling results would only be additive if these additional sources were also considered. The TechLaw air modeling did not attempt to evaluate air emissions from processes that operated on the USS Lead property previous to 1973. Insufficient data are available to draw defensible conclusions on the emissions that occurred from 1920 to 1973 when the facility was engaged in primary lead smelting. Nevertheless, the deposition patterns presented in the TechLaw air modeling report appear to be useful for reviewing previous soil sampling locations and designing plans for further sampling efforts. The TechLaw air modeling supports that soil sampling in off-site areas, such as nearby residential, may be useful for documenting areas impacted by emissions from the USS Lead facility.

### 3.0 SAMPLE COLLECTION

The samples considered in this study primarily were collected through two sampling events which took place in the summer of 2003. On-site samples, collected from within the USS Lead property boundaries, were split samples collected by TechLaw on July 9, 2003. Off-site samples, collected from residential and other locations not on USS Lead property, were collected by an EPA field team in July and August 2003.

A third set of samples also will be discussed in this report. These samples were collected from USS Lead, along Kennedy Avenue east of the USS Lead site, and Dupont property by TechLaw during a field event in 2002. Each of these field events is described in this section.

#### 3.1 On-Site Samples Collected in 2003

TechLaw conducted field oversight and split sampling activities at the USS Lead Site during Modified RCRA Facility Investigation (MRFI) field activities on July 8 and 9, 2003. TechLaw observed sampling activities at 24 locations on-site. On July 9, 2003, TechLaw collected split soil samples at 14 of these locations. Soil sampling activities were conducted in accordance with TechLaw's approved Surface Soil Sampling and Analysis Plan, dated July 8, 2003, and TechLaw's approved EPA Region 5 Generic Quality Assurance Program Plan (QAPP). Sample collection included the collection of all appropriate quality control (QC) samples. The TechLaw Field Oversight and Split Sampling Report is included in Appendix A.

The on-site samples analyzed for this study were collected from the zero- to six- inch (0-6") interval. All samples were collected by USS Lead representatives in accordance with the *Revised MRFI Work Plan Addendum, Revision 2*, dated May 30, 2003 (USS Lead, 2003). The samples were collected using a stainless steel spoon and bowl. The samples were homogenized and the sample containers for USS Lead and TechLaw were filled. Multiple sample containers were filled for TechLaw to allow split samples to be sent to multiple locations for analysis. The holes were filled in after sample collection. The split samples were maintained within TechLaw's custody at all times until they were shipped to the laboratories.

Of the 15 samples that were collected, only eight were selected for analysis in this study. USS Lead preliminary analytical results from the USS Lead aliquot of the split samples were reviewed by EPA and TechLaw to assist with the decision regarding which of the 15 samples to analyze. The eight samples that were selected for analysis were selected based on metals concentrations and location. The locations of the eight on-site samples selected for laboratory analysis are presented in Figure 3-1. The samples were shipped to American Analytical and Testing Services (AATS) and the Laboratory for Environmental and Geological Studies (LEGS) at the University of Colorado in Boulder.

#### 3.2 Off-Site Samples Collected in 2003

Off-site samples were collected during the period from July 23, 2003 through August 21, 2003.



These samples were collected in accordance with the *Quality Assurance Project Plan, USS Lead Refinery Inc. and Vicinity* (Project QAPP), dated July 2003 (EPA, 2003a) and the *USS Lead Refinery Inc. and Vicinity, East Chicago, Indiana, Sampling and Analysis Plan* (Off-site SAP) dated July 2003 (EPA, 2003b). The collection and XRF analysis of these samples are described in the *Report on X-ray Fluorescence Field Study of Selected Properties in Vicinity of Former USS Lead Refinery Facility, East Chicago, Indiana* (Off-site Report), dated November 2003 (EPA, 2003c). The description of the sampling presented here is taken from the Off-site Report.

As described in the Off-site Report, soil sampling for X-ray fluorescence (XRF) analysis was completed at 83 locations. Of these 83 locations only 20 samples were subjected to laboratory analysis. These locations are shown in Figure 3-2. Each of the 83 location was assigned an "x" identifier. The locations which were selected for laboratory analysis were also assigned an "s" identifier, in addition to the "x" identifier. Table 3-1 correlates the "x" and the "s" identifiers for the samples that were subject to laboratory analysis in this study and provides information on the properties that were sampled. As described below, several factors, including location and XRF results, were considered in the selection of samples to be subjected to laboratory analysis.

All samples were collected by either Michael Mikulka or Mirtha Capiro of U.S. EPA, or Mike Sickels of IDEM using the procedures identified in the SAP. Sample locations had not been identified in the QAPP or SAP since sample collection was dependent upon individual property owners granting access. Access was sought prior to or concurrent with each day's sampling activities, and property owners granting access usually had their properties sampled the same day or the following day, with some exceptions.

Soil for screening and sample collection was composited from a residential house yard or public area (vacant lot, park, ball diamond) using a 5 point composite in accordance with procedures described in EPA Guidance Document *Superfund Lead-Contaminated Residential Sites Handbook*, OSWER 9285.7-50 (Draft) October 2002; or, for industrial property, from a one (1) square meter area (m<sup>2</sup>) area. Typically, soil was scraped from upper 1-2 inches of the target areas using a pre-cleaned disposable plastic scoop or spoon, then placed in a pre-cleaned disposable plastic bowl or other container for homogenization. If the target area was covered with grass, the grass was cut away with a knife with a stainless steel blade and pulled back to expose the soil for sample collection. At industrial properties, a stainless steel shovel was used as necessary to clear tall grass from the areas where the composite sample was collected. Approximately 4 scoops of soil were obtained from each point in the 5-point composite, for a total of 20 scoops of soil.

Upon collection of the soil sample, the grass was replaced and tamped down. The bowl of sample material was transported back to the processing area, where grass, roots and rocks were removed manually (or in some cases with a Number 8 mesh stainless steel sieve), and the bowl labeled and covered with foil. If the soil was wet, the foil was pulled back and the bowl placed in the sun to allow the soil to air dry, while mixing periodically to allow drier surface soil to mix with wetter soil. Once the soil was sufficiently dry (depending on conditions, up to 4 hours drying time on some samples), 4-5 scoops of the sample were placed in a re-sealable 1 quart plastic bag for XRF analysis.

All XRF screening was conducted on a bagged sample, with XRF instrument readings expressed in parts per million (ppm). After screening, it was determined by the Field Project Manager in conjunction with the Project Manager whether to proceed with sample collection for laboratory analysis based on the screening result. Initially, the plan was to collect samples for laboratory analysis from all locations where the Pb XRF screening result exceeded 400 ppm. However, based on the first few samples screened (all exceeding 400 ppm Pb) it was determined that the number of samples sent to the laboratory would far exceed the initial target and therefore the allotted budget. Therefore, sample collection was cut back to meet the minimum requirements of the study based on the SAP (confirmation for at least 10% of samples screened, and at least 1 per field day) and also provide sufficient information to ascertain possible Pb sources based on proximity to both USS Lead and other potential industrial sources. Sample collection also included field duplicate collections from locations S03 & S07 (samples D03 & D07), and matrix spike/matrix spike duplicate (MS/MSD) sample collection from location S07 (sample M07).

Upon completion of sample processing, if soil screening levels for lead exceeded 400 ppm, and the sample location also met other goals of the project, then sample bottles were prepared from the sample bowl. Section 3.2 of the Off-site SAP, Selection of Screening and Sampling locations, explains the rationale for proceeding with sample collection for consideration for laboratory analysis. Upon filling and labeling, the sample bottles were placed in an iced cooler within the vehicle used for equipment storage and remained within the custody of the processing personnel.

Re-sampling was conducted at certain XRF screening locations that were not originally selected by the Field Project Manager (FPM) for sample collection for laboratory analysis, but were later determined by the Project Manager (PM) (after review of all XRF data) to be appropriate locations for sample collection, mainly to attempt to confirm the source of the Pb. Locations X07 and X08 were re-sampled on August 12, 2003, and location X20 was resampled on August 21, 2003, by Mirtha Capiro of USEPA. Re-sampling included 5 point composite sampling and homogenization as per the SAP, but did not include XRF screening. As such, the laboratory results from these samples will not be directly comparable to the XRF results, as they are not from the same sample. These three samples should be considered co-located samples to the samples which were screened by the XRF.

The samples were maintained under EPA custody until custody was transferred to TechLaw immediately prior to TechLaw shipping the samples. The samples were shipped to AATS and the LEGS at the University of Colorado in Boulder.

### **3.3 On- and Off-Site Samples Collected in August 2002**

On August 15, 2002, TechLaw conducted sampling at six locations in the vicinity of the USS Site. The sample locations may be seen on Figure 3-3. All samples were surface samples collected from an interval of 0-6 inches below ground surface (bgs) with the exception of sample SS-02 which was collected from a depth interval of 10-16 inches bgs. Because only a limited number of samples were proposed, TechLaw collected material from the specified sampling interval from three points within a one meter area. This approach was taken to minimize the influence of potential variability in the distribution of anthropogenic lead at each location (i.e., slag versus native sand contaminated with air-deposited material).

- Sample SS-01 was collected from the northwest face of a paleo-dune immediately west of an area that had historically been used to store uncontrolled piles of baghouse dust. The sample was dark brown, fine to medium grained sand with some organic material.
- Sample SS-02 was collected at depth from an on-site area to evaluate levels of metals in soils that were not significantly impacted by anthropogenic activities. They did not appear to be disturbed by operations at the site based on site reconnaissance and reviews of historical aerial photographs. The surface interval was not considered because of expected impacts from aerial deposition of lead from the site. The sample was light brown, fine to medium grained sand with minor organic material.
- Sample SS-03 was collected from a portion of the wetlands near the former slag pile. The presence of a thick (> 1 foot) vegetative mat in the area suggests that the area has not recently been a fluvial channel. The sample did not appear to contain mineral material larger than sand-sized particles suggesting the sample did not contain appreciable amounts of slag. The sample was grey, wet, silt and sand with abundant organic material.
- Sample SS-04 (and duplicate sample SS-07) was collected from a location along Kennedy Avenue, downwind from the former blast furnace location. The sample was brown, fine to medium grained sand with some larger particles, including some slag.
- Sample SS-05 was collected from a location downwind of the USS Lead site on Dupont Property. The location was selected because previous analytical results suggested that elevated levels of lead were found in the area. Although TechLaw strived to find a sample location that could be considered 'native sand potentially impacted by aerial deposition,' the sample location was found to contain abundant slag under a thin layer (< 1 inch) of sand. The sample could be characterized as abundant slag with some sand. The sample location for SS-05 was not selected based on any unusual site-specific characteristics (i.e., not selected based on vegetative stress, slag was present across most of this area).
- Sample SS-06 was also collected from a location downwind of the USS Lead site on Dupont Property. The location was selected away from the SS-05 area in attempt to characterize a more generally representative downwind area (i.e., not near the previously identified elevated concentrations of lead near location SS-05). The sample was collected from what appeared to be a sandy area between two medium-sized trees (4 to 5 feet apart, approximately 1 foot diameter trunks); using the rationale that the trees had been present in the area for a while and the area might contain more native sand and less slag than the surrounding, open areas. The sample was found to be abundant in slag with some sand.
- Sample SS-07 is a duplicate of sample SS-04. This sample was collected from a location along Kennedy Avenue, downwind from the former blast furnace location. The sample was brown, fine to medium grained sand with some larger particles, including some slag.

All samples were collected using the same method. A disposable plastic or steel spoon was used

to clear away leaf litter and debris. A second disposable plastic or steel spoon was then used to scoop soil into a plastic bowl. The soil was then homogenized, quartered, and transferred into the sample containers (eight-ounce unpreserved glass jars with teflon-lined lids). Four sample containers were filled from each sample location. Large organic material, rock, and slag were avoided when selecting the sample locations, and these particles were removed from the bowl or avoided when placing the soils into the sample containers. The samples were maintained under TechLaw's custody during additional sampling activities and immediately placed into a cooler with ice when the field team returned to the locked vehicles. The samples were shipped to Southwest Laboratory in Broken Arrow, Oklahoma (SWOK). Southwest Laboratory provided the samples to their partner laboratory, AATS, to conduct the analyses.

## **4.0 ANALYTICAL METHODS**

### **4.1 On- and Off-Site Samples Collected in 2003**

The on-site and off-site samples collected in July and August 2003 were all subjected to similar analyses. These analyses were similar to those conducted on the 2002 samples with the exception of the EMPA. The analyses are summarized in Table 4-1.

#### **4.1.1 Preparation/Sieving**

A portion of the samples sent to AATS were dried and then dry-sieved through a 150 micron screen. Following sieving, both a "fine" fraction (<150 micron) and a "residual" or "coarse" fraction (>150 micron) were weighed and made available for analysis. A "bulk" fraction, which was not sieved, was also available for analysis. This was an improvement over the 2002 study (see 4.2 below) where only a "fine" fraction and "bulk" sample were analyzed.

#### **4.1.2 X-Ray Fluorescence Analysis**

X-Ray Fluorescence analysis was conducted on the off-site samples by EPA. The methods are described in the Off-Site Report (EPA, 2003). Soil was collected from the sampling locations, homogenized, air-dried if necessary, placed in a sampling cup, and screened with a field-portable XRF unit. Appropriate QC procedures were conducted, as described in the Off-Site Report (EPA, 2003).

#### **4.1.3 Quantitative Analysis**

The quantitative analysis described in this report was conducted in accordance with EPA SW-846 Method 6020. Data was reported for 16 elements including 11 elements recommended for analysis under Method 6020 (antimony, arsenic, barium, cadmium, chromium, copper, lead, manganese, nickel, silver, and zinc), as well as 5 elements that can be quantitated by Method 6020 (calcium, iron, selenium, tin, and zircon). Contract Laboratory Program (CLP)-like data packages were presented for these analyses, which included all required QA/QC measures for full quantitation. There were no significant problems found in the QA/QC data and the analytical data can be considered usable for all purposes.

#### 4.1.4 Semiquantitative Analysis

Semiquantitative analyses were conducted using ICP/MS techniques similar to those used for the quantitative analysis. Data from raw data scans (integrated counts per second for each mass) were provided to TechLaw without quantification or semiquantification. The scans were conducted from the same prepared solutions that were used in the quantitative analysis (including the same standards, blanks, internal standards, and QC samples). Integrated counts per second were provided for every mass for  $m/z$  ratio (where  $m$  and  $z$  are mass and proton numbers, respectively) from 5 to 238, but ignoring any masses that would have caused harm to the instrument (i.e., 12, 14, 16, 18, 28, 32, 40, 80, etc.). The only additional QC sample that was run was NIST 981 common lead isotope ratio standard at the beginning and end of the scan run, at a concentration in the range of the samples. TechLaw received the data in electronic format and calculated concentrations for all of the detectable masses after importing the files into a spreadsheet and applying standard ICP/MS procedures for calculating concentrations. Unlike the quantitative analyses where the average of three integrations was used for quantitation, only one integration was provided for the semiquantitative scans.

The semiquantitative scans provided concentration data for the same 16 elements that were reported for the quantitative analysis. In addition, concentrations were derived for 9 other elements (beryllium, sodium, magnesium, aluminum, vanadium, cobalt, molybdenum, thorium, and uranium) which were included in the multi-element standards but were not reported in the quantitative analysis. All QC was passed. Except for use of one integration instead of three, the semiquantitative data for all 25 of these elements is nearly the same high quality as the quantitative analyses. Lastly, additional concentration data was calculated for 20 elements (gallium, germanium, rubidium, strontium, niobium, tellurium, lanthanum, cerium, praseodymium, neodymium, samarium, europium, gadolinium, dysprosium, erbium, thulium, ytterbium, hafnium, tungsten, and mercury), for which no standards were run, by using relative response factors. These data should be accurate within 20-30% of true values. It was possible to report additional elements, however there was no evidence of detectable quantities in any of the samples. Background levels for the geographical area and crustal abundance levels for the detected elements should be considered before attributing any detected element levels to anthropogenic sources.

#### 4.1.5 Lead Isotope Analysis

Lead isotope analysis for the on- and off-site samples collected in 2003 was conducted as part of the semiquantitative analysis. Integrated counts per second were requested by TechLaw for each of the four isotopes of lead (i.e., 204, 206, 207, and 208). As requested, the NIST 981 common lead isotope ratio standard was run at the beginning and end of each scan run.

In the 2002 study, a special lead isotope ratio ICP/MS analysis procedure was performed on the samples. However, this procedure was prohibitively expensive and would have been an additional \$200 per sample for the 2003 study. This extra cost was avoided by using the semiquantitative analysis scans of the lead isotopes. Offline calculations of isotope ratios were performed in a

spreadsheet, and plotted in the same way as the 2002 data. The disadvantage of having only one integration for semiquantitative scans versus three integrations for the special lead isotope ratio analysis procedure was mitigated by the high levels of lead in the samples. The high concentrations of lead in the 2003 samples gave ample signal for each isotope. Mass bias correction factors were also applied offline to the semiquantitative 2003 lead data whereas, they were automatically applied to the 2002 data. A last concern was the presence of an abundance sensitivity problem in the semiquantitative analysis scans. The problem is caused by signal tailing from a high signal mass into the adjacent lower mass. All masses were checked for this problem and corrected when possible. However, the correction on mass 204 often exceeded the signal due to the minor lead 204 isotope. Consequently, use of mass 204 was avoided.

#### **4.1.6 Electron Microprobe Analysis**

The electron microprobe analysis (EMPA) was conducted by Dr. John Drexler at the LEGS laboratory at the University of Colorado at Boulder. Samples received by the LEGS for EMPA analysis were not sieved. EMPA preparation techniques such as mixing with epoxy resin, grinding, and polishing are described in the LEGS Lead Speciation Lab Report (LEGS, 2003), included in Appendix B, as well as in the EMPA Standard Operating Procedure available on the LEGS website at <http://www.colorado.edu/geolsci/legs/speciation1.html>. Generally, a "puck" consisting of resin and several grams of sample is examined in the electron microprobe instrument. Traverses are made across the sample at two different magnifications (i.e., 40 to 100X and then 300 to 600 X to identify the smallest, 1 to 2 micron phases). The operator's objective was to count at least 100 lead-bearing particles per sample. If analysis becomes too time consuming then the operator may spend only eight hours analyzing each sample.

#### **4.2 Samples Collected in 2002**

The six samples that were collected in 2002 were sent to Southwest Laboratories of Oklahoma (SWOK). Because of the specific analyses that were requested by TechLaw, the samples were prepared and analyzed by the SWOK partner laboratory AATS, similar to the on- and off-site samples. Portions of the samples were dry-sieved through a 150 micron (100 mesh) screen to represent a "fine" fraction. "Bulk" samples for each location were also analyzed. Quantitative analysis was conducted in accordance with EPA SW-846 Method 6020. In addition, a lead isotope scan was conducted using NIST standard 981. Lead isotope analyses were performed by a special procedure designed by the instrument manufacturer specifically for lead isotope ratio studies. As mentioned above, this special procedure was not applied to the 2003 samples.

### **5.0 RESULTS**

#### **5.1 Chemical Data**

The weight fractions, in grams, of the fine fraction passing through the 150 micron sieve and the residual fraction retained in the screen are presented in Table 5-1.

Table 5-2 presents the quantitative results from the 2003 sampling. Table 5-3 presents the

semiquantitative results from the 2003 sampling, including the lead isotope results. Table 5-4 presents the quantitative data from the 2002 sampling.

X-ray Fluorescence analytical results are presented in the Off-Site Report (EPA, 2003). Figure 5-1 graphically presents off-site XRF results for lead in the area north and northeast of the USS Lead site.

## 5.2 Lead Isotope Data

The values were plotted on coordinate systems with 208/206 ratios plotted on the Y axis and 207/206 ratios plotted on the X axis, which is a typical way of displaying lead isotope ratio data for lead sourcing. These plots are presented as Figures # through #. In each figure, the results for the NIST 981 standard are plotted, but they routinely show in the upper right of each graph. Because NIST has created a "common" lead standard does not mean that it contains average amounts of each lead isotope for all sources of lead. In fact, NIST 981 seems to have about 3% less of Pb 206, and 3% more of Pb 207 than many common lead samples. For example, the following link, <http://www.epa.gov/nerlesd1/pdf-ecb/059ecb98.pdf> shows NIST Bone Ash SRM 1400 with 208/206, 207/206 ratios of 2.094, 0.858, respectively, which is very much in agreement with the levels shown in the USS Lead samples. The QC standards used in this study were probably prepared from a common source of lead salts.

In Figures 5-5, 5-6 and 5-7, the QC samples are shown to agree better with the USS Lead samples than they do with NIST 981. In any case, any shift towards NIST 981 will be interpreted as moving towards a more common lead source. Looking at these other two sources of lead, the USS Lead isotope ratio signature is about as "common" as one can get. Other results shown in Figures 5-2 through 5-4 include pairing of the coarse and fine fractions for each sample. The pairs are connected by an arrow with the arrowhead pointing to the fine fraction. These arrows could be interpreted as shifts in isotope ratio when going from coarser to finer particle size. Trends in the arrows may indicate information on how the lead is distributed. Tabulated lead isotope ratio data from the 2003 sampling is presented in Table 5-3.

## 5.3 EMPA Results

The EMPA *Lead Speciation Lab Report*, dated October 24, 2003 and submitted by Dr. John Drexler of the LEGS, is provided as Appendix A to this report. The report summarizes the EMPA point count data as frequency of occurrence (F) for each type of lead-bearing particle that was observed and the relative lead mass (R) that may be assigned to each particle. The relative lead mass is based on the frequency of occurrence of a phase as well as the specific gravity and concentration of lead associated with the phase. The specific gravity and concentration data used by LEGS to calculate R is presented on Table 1A on Page 63 of the LEGS El Paso Report, presented in Appendix B of this report. The EMPA results from the on- and off-site samples is also presented in Table 5-5. Bar charts which graphically present the EMPA data are presented in Appendix C. Photomicrographs, chemical spectra, and individual particle point-count data is presented in Appendix D on the enclosed CD.

## 6.0 DISCUSSION

### 6.1 Chemical Data

The fine and residual fraction sieve results presented in Figure 5-1 are translated into percentages. These percentages give some information about the relative abundance in the sample of material finer than 150 microns but the primary purpose of sieving the samples was to assess the concentrations of metals in the fine fraction relative to the coarse fraction.

The samples collected in 2002 were sieved in the same manner as those sampled in 2003. However, the laboratory analyzed fine and bulk fractions in the 2002 study, as opposed to fine and residual fraction in the 2003 study. There are several reasons for this difference in approaches including cost and project objectives as they relate to chemical data on bulk samples. In the 2002 study, results from bulk sample analysis was deemed necessary to facilitate comparison to screening levels and other data from the vicinity of the site. For the 2003 study, XRF data was available for each of the off-site samples. The bulk samples that were analyzed in the 2003 study were analyzed to assess the performance of the XRF results and to facilitate comparison of some sample results to screening levels.

During a review of the quantitative data, TechLaw observed that it is difficult to reconstruct the analytical results from the bulk samples from the fine and coarse data. Typically, it should be possible to approximately recalculate the bulk data from available fine and coarse data. However, it seems clear that the analytical results provided for the bulk samples are consistently higher than would be expected if the bulk was calculated based on weight fraction and concentration of the fine and coarse. All of the quality control (QC) data related to the quantitative analysis of the bulk, fine, and coarse samples indicates that there are no apparent reasons for the bulk results to be higher than the result derived by calculating a bulk result from the fine and the coarse fractions. It seems apparent that non-representative bulk samples may have been analyzed, the coarse fraction material may not have been pulverized representatively, or some other sample preparation procedures were taken that affected the representativeness of the bulk samples relative to the fine and coarse samples. [should be - Upon close inspection, it seems clear that the lab dried the bulk samples before taking an aliquot for analysis. They then applied the moisture correction when generating the data packages. They should not have applied moisture corrections when reporting samples on a dry weight basis and starting with a dried sample. Consequently, the values the lab reported are biased high by the amount of the moisture correction for each sample. Due to business reorganization issues, the technicians and the laboratory that were used to analyze the samples were not available to verify this suspected reporting error. The data presented in this report corrects this apparent reporting error.]

In both fine versus bulk and fine versus residual comparisons it is possible to assess whether metals are primarily concentrated in the fine fraction or not. In the 2003 data, a clear trend may be seen that, in most samples, most metals are concentrated in the fine fraction. One factor likely to be a contributor to this observed concentration in the fine fraction is the deposition of fine particles within the study area through air dispersion of industrial emissions. This interpretation supports an aspect of the USS Lead facility's conceptual model for the site which includes the



potential for fine particulate matter from USS Lead smelting operations as a source of lead and other metals in the study area (USS Lead, 2004). Although the deposition of fine particulate matter from smelting processes may be a source of lead and other metals in the study area, EMPA results indicate that lead bound in metal-oxides, -hydroxides, and other soil-forming phases is also common in the study area. Some of the soil forming phases may also contribute to the observed concentration of lead in the fine fraction. Some of the lead and other metals deposited in the study area may be weathering to soil forming phases.

Kriging is a statistical technique that interpolates values graphically in a data set. When Kriging is applied to the XRF concentration data for the off-site portion of the study area, north and northeast of the USS Lead site, it may be seen that the lowest concentrations of lead primarily occur in the northeastern portion of the study area and the extreme northern portion. These areas are shaded green on Figure 5-1. A comparison of the laboratory analytical results to the field XRF results for lead is presented in Table 6-1.

Kriging is used on additional figures in this report to show trends in the distribution of metals in the study area based on concentrations associated with the fine and residual fractions. Although the on-site concentrations are not directly comparable to the off-site concentrations due to differences in the sample depth intervals (i.e., 0-2" off-site versus 0-6" on-site, the greater interval used for the on-site samples is expected to have a diluting effect on the concentrations) figures displaying the data together are still useful. The greater sampling interval in the on-site areas is non-conservative, relative to the off-site data. Therefore, trends which involve the 0-6" on-site data will tend to minimize the impact of the on-site data relative to the off-site data. Conversely, the USS Lead on-site samples are the only "on-site" sample locations from an industrial source displayed in the figures so the elevated levels of metals in the on-site USS Lead samples may emphasize elevated concentrations at the USS Lead site relative to the off-site areas. These points are mentioned here to qualify the potential interpretations of the information presented in Figures 6-1 through 6-20.

The elements that are presented in Figures 6-1 through 6-20 were selected based on their occurrence in the study area at concentrations exceeding average crustal abundances. Crustal abundances of elements in various rock types are presented with the semiquantitative data presented in Table 5-3. The ten elements identified at levels generally exceeding average crustal abundances and that are plotted on Figures 6-1 through 6-20 are antimony, arsenic, cadmium, copper, iron, lead, manganese, selenium, tin, and zinc.

It was not possible to collect source material and emissions information from all of the facilities that may have potentially influenced the study area. Therefore, the interpretations that are presented in this report are limited. Tin concentrations appear to be elevated in the southern portion of the residential neighborhoods relative to the northern portion of the neighborhoods. Zinc concentrations are lower immediately north of the USS Lead site relative to other portions of the study area. The low relative zinc concentrations could be related to a low-zinc source influencing metals concentrations in this area, such as USS Lead. Zinc concentrations in on-site samples at USS Lead do not appear to be elevated relative to zinc concentrations in off-site areas.

USS Lead formerly conducted tellurium-related operations on site. Therefore, tellurium may be a chemical marker unique to USS Lead. Following a careful analysis of the semiquantitative data, the presence of tellurium, based on detection of 5 different tellurium isotopes at the correct ratios, was verified at levels that were several hundred times crustal abundance background levels. Coupled with the presence of the tellurium plant on USS Lead property, and tellurium's major use as an additive to lead to prevent corrosion, the tellurium-lead connection would most likely be associated with lead recycling rather than raw ore processing. If the other smelters in the area just processed ore (which typically has insignificant amounts of tellurium), they may essentially not have contributed any tellurium to the study area. Although concentrations of tellurium are elevated in on-site and some off-site areas, it is not clear at this time (i.e., without additional tellurium distribution data) whether tellurium may be used as a definitive marker for USS Lead contamination.

USS Lead was the only property that was sampled in 2003 that is a potential source of air emissions to the study area. Since there were no other "on-site" samples collected from other potential source facilities, this report does not intend to skew the available data relative to USS Lead's potential contribution to lead and other metals in the study area. Nevertheless, the available data, even in consideration of the diluting influence of the 0 to 6" on-site sampling interval, suggests that antimony, arsenic, copper, lead, and possibly tin are present at the USS Lead site at concentrations greater than in off-site areas sampled during this study.

Through a general comparison of the tabulated data presented in this report and the sampling locations presented in the figures some broad chemical distribution trends may also be observed across the study area. It is not clear whether these trends are related to variations in the bedrock, influences from the river sediments, industrial sources, or other influences. For example, aluminum and magnesium concentrations are generally higher in the northern part of the study area than in the southern portion. Without additional study it is not clear whether the aluminum concentrations in the northern portion of the study area are related to the US Reduction Aluminum facility which is located north of Chicago Avenue in the area adjacent to the Calumet neighborhood. Several minor and trace elements also follow this trend, especially in the fine fraction, such as beryllium, dysprosium, erbium, europium, gallium, gadolinium, neodymium, and praseodymium. Gallium, hafnium, and tellurium appear to be present at higher elevations on the USS Lead property relative to off-site areas.

During the 2002 sampling, sample SS-02 was collected from the upland area in the western portion of the site. This sample was collected from the 10 to 16 inch depth interval to minimize the influence of concentrations of metals at the surface. A significant concentration in the fine fraction was observed for lead in this sample.

## **6.2 Lead Isotope Trends**

The lead isotope data from the 2002 sampling displayed a wide range along the isotope ratio distribution line. The ratios of 208/206 and 207/206 were plotted on a coordinate system. The ratios observed in the samples collected from the USS Lead site were higher than the samples collected from the Dupont site and more similar to the NIST 981 "common" lead sample than the

Dupont samples. The observation of higher 208/206 and 207/206 ratios in the USS Lead samples is interpreted to be a signature of the lead from the processing of batteries in the secondary smelting operations at the USS Lead site (i.e., many sources of lead in the batteries, mixing of these sources through the smelting process). The position of the Dupont samples relative to the USS Lead samples suggests that the lead in samples SS-05 and SS-06 may be from a distinct source relative to the lead in samples SS-01 and SS-03, for example.

Other than USS Lead in 2002 and 2003, and Dupont in 2002, no samples were collected from other potential source facilities which may have contributed contaminants via air emissions to the study area. Although little information was available about the Anaconda Lead Smelter, the International Lead Refining Company, the Eagle-Picher Mining and Smelting, Inc. operations in the vicinity of the USS Lead site, the lead isotope signatures from these potential sources may be similar to the signature from USS Lead if operations and source materials were similar. Therefore, this study does not attempt to rely on isotope analysis to distinguish between lead sources, with the exception of those sources related to USS Lead and Dupont.

Although the observed trend in the USS Lead samples, relative to the Dupont samples, is not conclusive, it appeared to be consistent with the observation that there was an observed shift, along the trend line, in some samples such that the fine fraction signature was closer to common lead than the bulk fraction. The common lead directional shift in the fine fraction appeared to support the model that fine material in the study area may have been generated through the smelting process at USS Lead. Such material could have been transported by wind and deposited. Shifts from the coarse to the fine fraction in lead isotope plots may be useful as a tool to identify contributions from air emissions if the isotope signature of the fine fraction is distinct from the coarse fraction.

Generally, shifts that are perpendicular to the trend line may be attributed to random precision factors while shifts along the trend line may result from the same random precision factors plus additional shifts due to differences in the sources of lead in the samples. To see the effects of precision, Figures 5-5, 5-6 and 5-7, with QC, show plots of the same continuing calibration verifications (ccv) samples run multiple times. They demonstrate the extent of random errors in the plots and should form a circular "cloud" about the true mean for the ccv's isotope ratios. As other samples are included in the data set, any elongation of the "cloud" of data points along the distribution line will be due to differences in lead sources. The only sample that seems to be a clearly different source of lead is the soil lab control sample (lcss).

Generally, the 2003 on- and off-site lead isotope data does not show the range in isotope ratio distribution that was observed in the 2002 data. For example, the 207/206 ratio of the 2002 data ranges approximately from 0.77 to 0.86 while the 207/206 ratio of the 2003 data ranges approximately from 0.82 to 0.845. When plotted on the same scale as the 2002 data as in the chart on Figure 5-8, the 2003 off-site and on-site data are more confined in the central area of the plot where USS Lead data was located in the 2002 data. Thus, the two data sets appear to be consistent. The signature for samples SS-05 and SS-06, with 208/206 ratios below 2.02 and 207/206 below 0.80 that were seen in 2002 data, appear to be clearly different from the ranges seen in the on-site and off-site data from 2003. Based on this comparison, it seems clear that there is no clear Dupont signature observed in the off-site samples.

As shown in Figure 5-4, the "cloud" of off-site data is elongated along the distribution line; However the data is clearly strongly influenced by random precision. For example, lead isotope data was plotted for samples S07 and M07. Because an MS/MSD was requested for sample M07, the sample was analyzed multiple times in the semiquantitative analysis. The spike solutions would be expected to have negligible effects on the isotope data. The plotted values for S07, M07, M07L, M07s, M07sd show a wide range in variability spanning approximately across 50% of the "cloud" of data from the 2003 lead isotope data. The typical variability observed within this single sample, along with the limited range along the trend line described above, appear to limit the conclusions that may be drawn from within the "cloud" exhibited by the off-site 2003 isotope data.

Compared to the off-site samples, the isotope ratio data from the on-site locations shown in Figure 5-3 showed a more elongated "cloud" following the distribution line, and shifted more to the NIST 981 common lead direction, despite the effects of random precision. Another way of looking at the data is using the shift arrows between coarse and fine data pairs. The arrows between coarse and fine pairs of the on-site data set seem to shift more along the distribution line rather than perpendicular to it (of the 12 data pairs, 10 shifted along the line whereas 2 shifted perpendicular). In contrast, the arrows between coarse and fine pairs for the off-site samples showed an even distribution of shifts along the distribution line and perpendicular to it (of the 25 data pairs, 12 shifted along the line and 13 shifted perpendicular to it). Thus, the off-site samples are clearly dominated by precision effects and conclusions about lead sourcing within that data set will be difficult. However, among the on-site 2003 samples, this may not be the case. It appears TL-7, TL-17, and TL-9 may have different source signatures outside of precision effects, even though they are still within what would be considered the common lead region. Likewise, samples SS-01 and SS-03 are dominated by clearly different sources as SS-04, SS-07, SS-05 and SS-06 in the 2002 data set.

Sample location SS-02 in the 2002 sampling event was collected from 10-16" bgs. The purpose of collecting this sample from a remote portion of the USS Lead site, at depth, was to evaluate the concentrations of metals in material interpreted to be native sand, assumed to be less impacted by industrial processes than surface material. The lead isotope signature of sample SS-02 displays a pronounced shift away from common lead from the bulk to the fine fraction. Physical processes such as weathering would not be expected to differentially partition isotopes of lead. Therefore, it is likely that the directional shift away from common lead observed in sample SS-02 is related to different source materials rather than physical processes. Because the concentration of lead in sample SS-02 was low, relative to the surface soil samples collected from the USS Lead site (15.9 mg/kg in the bulk fraction, 211 mg/kg in the fine fraction) it is possible that the observed directional shift is due to the relatively low isotope ratio signature of the "native" lead that is present in the study area. Similar to other samples analyzed through EMPA in this study, the observed concentration in the fine fraction relative to the coarser fraction may be related to lead associated with fine particulate matter or iron and manganese oxides and hydroxides and other soil forming phases. Since these soil forming phases may not be durable when subjected to mechanical activities such as sieving, fine particles originating from these phases could have become concentrated in the fine fraction of sample SS-02.

### 6.3 EMPA

An example of the application of EMPA for assessing the impacts of smelter emissions on a community is provided in *A Study On The Source Of Anomalous Lead and Arsenic Concentrations in Soils From the El Paso Community - El Paso, Texas*, dated June 5, 2003, (El Paso Report) prepared by Dr. John Drexler at the LEGS (Drexler, 2003). A copy of this El Paso Report included in this report in Appendix C.

In the El Paso Report there is a discussion of the complexity related to assigning certain phases to certain processes or sources. For example, anglesite ( $\text{PbSO}_4$ ) may be related to smelting operations, especially those associated with car batteries where the lead may complex with sulfuric acid, or it may be associated with lead-based paint. Other potential sources are also possible. However, it is useful to evaluate the observed phases in the broader context of the study. Study-specific factors such as location, source, and former facility operations may help assign a reasonable context to each phase. To continue with the example of anglesite, over 90% of the lead in on-site sample TL-7 was attributed to an anglesite phase, TL-7 was in an unremediated portion of the USS Lead site and TL-7 contained the highest concentrations of lead detected in this study (greater than 80,000 mg/kg). Based on these factors it seems reasonable to attribute anglesite identified in EMPA analysis to former operations at the USS Lead site.

No attempt was made in this study to apportion each phase detected in off-site samples. However, the suite of phases detected in on-site samples was considered along with other geochemical factors to present the relative lead mass data from the EMPA analysis in an illustrative manner. For example, as discussed above, it seems reasonable to attribute the anglesite in samples to USS Lead smelting operations rather than, for example, lead-based paint. Each of the phases detected in the EMPA analysis has been presented in bar charts in an order designed to illustrate relative lead mass related to smelting or metallurgical processes, phases related to "anthropogenic" sources such as paint and brass, and phases related to weathering and soil formation such as iron and manganese hydroxides. This data is summarized in Figure 6-21 in stack charts overlaid on the study area.

Although the presentation of the stack charts and bar-chart figures (Draft, presented in Appendix C) do not apportion phases, a signature may be seen when reviewing on-site data relative to off-site data. Generally, phases that relate to smelting metallurgical processes are more common in on- relative to off-site areas. Further, phases associated with soil forming processes are more common in off-site areas than phases associated with smelting or metallurgical processes.

### 7.0 CONCLUSIONS

Chemical data indicates that soils in the vicinity of the USS Lead site have elevated levels of lead and other metals such as antimony, arsenic, copper, tin and zinc. Not all of these metals are present at levels exceeding human health screening levels such as the EPA Region 9 Preliminary Remediation Goals (PRGs), Soil Screening Levels and relevant State criteria. However their distribution may provide information on potential source areas.

An evaluation of trends with respect to industrial sources in the vicinity of the study area suggests that the area may have been influenced by a variety of sources. Source influences appear to vary across the study area. For example, the distribution of Zn concentrations in the area immediately north of the USS Lead facility suggests that the area may have been subjected to lead deposition from air emission from predominantly a low-zinc source, such as USS Lead. Anthropogenic factors such as landscaping, gardening, and the import of clean fill may have occurred in the study area. It is not clear whether some of the lower concentrations observed in some of the residential neighborhoods are related to decreased industrial inputs in those areas or dilution due to anthropogenic processes.

Lead isotope data from the 2002 sampling indicates that lead from the USS Lead site may have a distinct signature relative to lead from the Dupont site. The lead isotope data from the 2003 on- and off-site data does not display as much variation along the trend line as the 2002 data. However, in general terms it appears that the on-site lead isotope data from the 2003 sampling plots closer to the NIST 981 common lead standard than the off-site lead isotope data. Some sourcing may be possible within the on-site data set, however, precision will not allow any sourcing within the off-site data set. Further, the lead isotope signature of the off-site data is more similar to the 2002 USS Lead lead isotope signature than the 2002 Dupont lead isotope signature. None of the off-site samples appeared to have the low ratios that were observed in the 2002 Dupont samples therefore there is currently no indication that lead similar to that sampled at the Dupont site in 2002 is a significant influence in the study area. In the absence of lead isotope data from other potential sources in the vicinity of the study area it is not clear whether the USS Lead signature observed in the study area is diagnostic as a source indicator.

EMPA results suggests that a significant amount of the lead within the study area may be complexed with iron and manganese hydroxides and other soil forming phases. Many lead phases that result from smelting processes do not typically have high solubilities. However, due to their small particle sizes, and relatively large surface areas, it is possible that airborne particulates carried into the off-site areas contributed a significant amount of the lead that is observed in the soil forming phases.

## 9.0 REFERENCES

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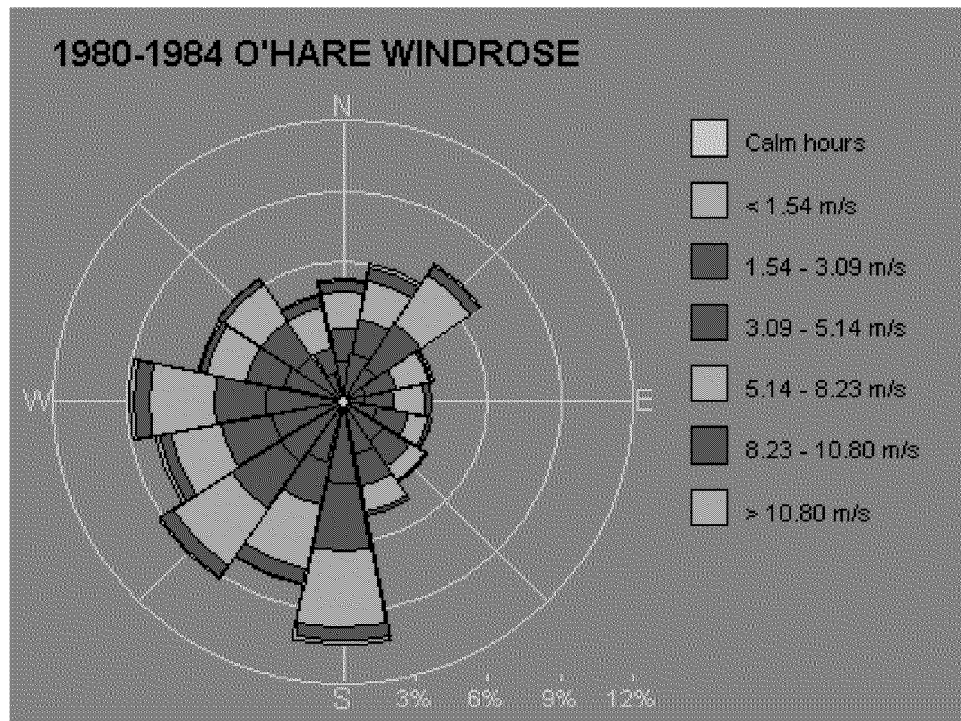
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## FIGURES



**Figure 2-7. Wind Rose for O'Hare National Weather Service Data, 1980-1984**





## TABLES

## **APPENDIX A**

### **Lead Speciation Lab Report**

**Prepared by the Laboratory for Environmental and Geologic Studies, October  
24, 2003**

## **APPENDIX B**

### **El Paso Report Prepared by the LEGS Laboratory**

**APPENDIX E**  
**EMPA Bar Charts**

## **APPENDIX D**

### **EMPA Photomicrograms, Chemical Spectra, and Individual Point Count Data**